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ABSTRACT

This discussion paper examines the training citizen groups need in order to confront a wide variety of industries and types of pollution. Section I of the paper focuses on the interaction of three groups: (1) industry: this group includes distributors of environmental pollutants as well as manufactures of pollution control equipment; (2) government regulators; and (3) citizens. Section II reviews Swedish environmental legislation and the factors that lead to the development of a partnership type relationship between industry and regulators thus creating a need for citizens to act as environmental police. Section III examines the education, training, and information environmental organizations need in order to confront a wide variety of industries. Section IV discusses efforts to educate the public as a "first line of defense," and presents the details of two major information campaigns, one involving opposition to nuclear energy, and the second directed towards environmentally safe energy sources for the future. Section V looks at the knowledge necessary to confront different industries that have different forms and mechanisms of pollution, within a legal context, and provides the technical contents of a licensing board hearing and a court action as an example. (LZ)

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TRAINING discussion PAPERS

Training for environmental law enforcement in Sweden

by Björn O. Gillberg & Arthur R. Tamplin

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Discussion Paper No. 105

Training for environmental law enforcement in Sweden: the role of NGOs

by Björn O. Gillberg & Arthur R. Tamplin
Miljöcentrum, Uppsala, Sweden

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I. Introduction

Environmental protection is a multi-faceted problem. One of the major aspects of this protection involves the release of pollutants into the environment. This report is directed toward this problem.

The environmental pollution battlefield involves the interaction of three groups. These are:

1) Industry: This group includes the generators and distributors of environmental pollutants. However, it is important to note that this group also includes the manufacturers of pollution control equipment.

2) Government: This group includes the lawmakers who are responsible for creating environmental protection legislation. It also includes the governmental agencies that are responsible for enforcing the environmental legislation. Moreover, these agencies often promulgate various pollution control regulations. It is important to note that the government is also a potential polluter; because, some of its agencies are responsible for waste disposal, sewage treatment, district heating and electricity generation.

3) Citizens: This group has the ultimate responsibility for the protection of the environment. The citizens must elect environmentally friendly lawmakers. Unfortunately, citizens must also act as environmental police to en sure that the governmental agencies are adequately enforcing the environmental legislation.

In fulfilling their responsibility toward combating pollution, some citizens have united to form environmental organizations. These organizations have found that they are usually engaged in a battle with both industry and the regulators. This occurs because a partnership type relationship develops between the regulators and the polluting industries that their agency is supposed to regulate. This relationship causes the regulators to offer more protection to the polluting industries than to the environment. Generally, it appears that the regulators are unaware of (or, more likely, simply choose to ignore) the potential of the products produced by the industries that manufacture pollution control equipment.

These observations have caused us to reach the conclusion that, with respect to the training of regulatory agency and industry personnel, there is a serious need for a basic course in integrity. Subsequent sections of this report will serve to illustrate the basis for this conclusion.

As a result of this apparent conspiracy between the regulators and the regulated, environmental organizations are forced to be both the first and the last line of defense in the battle to protect the environment from pollution.

In the first line of defense, these groups must educate the citizens concerning existing and potential environmental problems. They must also inform them of the nature of the environmental legislation required to eliminate the source of these problems. This allows the citizens to apply pressure at the ballot box. In addition, these groups must inform citizens about hazardous products. This allows citizens to exert pressure in the marketplace.

The last line of defense involves the environmental organizations acting as police to ensure that the regulators are enforcing the environmental protection laws. In this role, the organizations must, when necessary, appear at administrative hearings and present arguments to counteract the proposals of the industries. These organizations must also, when necessary, take the industries and/or the regulators into the courts of law.

II. Swedish environmental legislation

The Swedish government has a cabinet level office for the environment (Ministry of the Environment). The Ministry has the final authority on all pollution permits. But the major tasks of environmental protection are conducted by two independent agencies; the Swedish National Environmental Protection Board and the National Licensing Board for Environmental Protection.

The Swedish National Environmental Protection Board was created by an act of Parliament in 1969. This Board has the ultimate responsibility for supervising the enforcement of environmental legislation in Sweden.

The National Licensing Board for Environmental Protection has the power to grant permits to anyone performing or intending to undertake an environmentally hazardous activity. The Board may issue such a permit after examining the activity in accordance with the Environmental Protection Act (1969:387). As part of this examination, the Licensing Board conducts public hearings on permit requests. The Environmental Protection Board and the citizens may participate in these hearings.

According to the Environmental Protection Act (1969:387): The Licensing Board for a particular decision is composed of a chairman and three other members. The chairman should be well versed in legal matters and experienced in performing legal tasks. One member must have expert knowledge and experience of technical matters. One member must have experience of matters falling within the sphere of the National Environmental Protection Board's activities. The fourth member must have experience of industrial activities.

While the Licensing Board sets numerical limits when issuing permits, the Licensing Board is not bound by numerical limits for the release of pollutants. Rather, the Environmental Protection Act (1969:387) states in Section 5: Anyone performing or intending to perform an environmentally hazardous activity shall take such protective action, tolerate such restrictions of the activity and take such other precautionary measures as may reasonably be demanded for preventing or remedying detriment. The duty to remedy detrimental effects remains after the activity has ceased.

The extent of the obligation imposed by the provisions of paragraph one above is to be assessed on the basis of what is technically feasible for the activity in question, and taking both public and private interests into consideration.

In assigning priorities between various interests, particular attention shall be paid, on the one hand, to the nature of the area that may be subjected to disturbance and the severity of the effects of the disturbance and, on the other hand, to the usefulness of the activity, the cost of protective action and other financial implications of the precautionary measures concerned.

This text directs the Licensing Board to set numerical limits that are based upon a risk/cost/benefit analysis. This approach permits the formation and existence of a conspiracy between the regulators and the regulated. Unless someone represents the citizens at the hearings, this risk/cost/benefit analysis is totally biased in favour of the polluter. One reason for this is that the regulators ignore the important consideration that it is the citizens who take the risk and the polluters who receive the benefit. Another reason is that the cost to the citizens is minimized while the cost to the polluter is exaggerated.

But, even with citizen participation, the decisions are usually still biased in favour of the

polluters. This bias is even more regrettable; because, a citizen's only redress to the decisions of the Licensing Board is to appeal to the Ministry of the Environment. The decisions of the Ministry of the Environment are final and can not be appealed in the courts.

Unfortunately, the sole judicial remedy open to citizens occurs only after their health and/or property has been damaged by the pollution released by the industry. The citizens can then go to the courts and sue the industry to obtain monetary compensation for the damage to their health and/or property.

There are three other regulatory agencies that are of environmental importance in Sweden. The Food and Drug Administration regulates the content of foods. The Chemical Inspectorate regulates the sale of materials such as pesticides. The Radiation Protection Institute regulates exposure to radiation. These agencies operate under guideline that are similar to those for the Licensing Board and the Environmental Protection Board. However, these agencies do not conduct public hearings.

We will use two battles, a Licensing Board hearing and a court case to illustrate the nature of the environmental battlefield and to demonstrate the absolute necessity for introducing an army of environmentalists. But first, it is essential to discuss the education and training of the environmental armies and, even more importantly, it is essential to discuss the ammunition (information) required by these armies. Clearly, it is of little value to know how to fire a weapon if you have no ammunition.

III. Education, training and information

Environmental organisations need the knowledge necessary to confront a wide variety of industries. These industries have different forms and mechanisms of pollution and, therefore, have different requirements for pollution abatement and/or control. Figures 1 and 2 serve to illustrate these points. (The Figures are on pages 23 and 24)

The first column in Figure 1 tabulates the different types of industries that environmental organizations have to confront. The asterisks indicate those types of industries that Miljöcentrum has confronted in licensing hearings or in court proceedings.

The second column in Figure 1 tabulates information that is required to properly characterize the pollutants. The third column relates to the mechanisms for the spread of the pollutant throughout the environment. The fourth and fifth columns are concerned with the effects (physical and/or biological) of the pollution.

It is essential that each of the second through fifth columns be considered in the analysis of the potential environmental effects of any pollutant that is released. For example, if a city that has an irritating problem associated with the smoke from coal fires released through the chimneys of its surrounding industries, the city could solve this problem by increasing the height of the chimneys. The smoke would then come to earth downwind of the city and would be at a lower concentration. However, higher chimneys would only solve part of the overall problem. The fumes from the chimneys would still contain the compounds that produce acid rain and the carbon dioxide released would cause climatic change by augmenting the atmospheric greenhouse effect.

In a licensing hearing, the analysis proceeds from column 2 through column 5 and the industry is required to supply the data and information. In a court proceeding, the flow is from column 5 back to column 2 while the data and information are supplied by the plaintiff. Of course in both cases, there will be controversy over the data and information presented and both sides may present their own point of view.

Type. The type of source is important in determining the subsequent dispersal of the pollutants. A point source can be represented by a factory's chimney or a pipe discharging into a river. A volume source can be represented by a refinery that has multiple release points over a large area or a burial site for municipal wastes. A line source can be represented by the traffic on a highway. A product source can be a prepared food for grocery stores or a pesticide for farm use. A product such as a pesticide can become another source of pollution when, for example, it is sprayed on a crop by a farmer.

Emission. The spread of a pollutant throughout the environment depends upon whether the pollutant is released in the air, water or the ground. For releases to the air, it also depends upon whether the release occurs at group level or at some height above the ground. For releases to water, the spread will depend upon the depth of release and upon whether the waterway is a river, a lake, a bay, a sea or an ocean. The spread of releases to the ground will also depend upon the depth of the release point.

Nature of the pollution. The nature of the pollutants is also important in determining its dispersion; for example, large particles fall out of the atmosphere close to the source, while small particles can remain suspended in the atmosphere and travel completely around the

earth. The nature of a pollutant is also directly related to its environmental effects.

The nature of the pollutant is determined by using a variety of analytical techniques, both physical and chemical. These techniques are well developed today, but some of them require elaborate and expensive equipment and they must be performed by experienced technicians. As a consequence, such analyses are usually contracted out to consultants who have the necessary equipment and expertise. Generally, environmental groups need such analyses only for use in court.

The dispersion of pollution (see Figure 1, column 3) is important because, except for products, it determines the concentration of the pollutants at points distant from the source. The concentration of a pollutant is, of course, correlated with the magnitude of its environmental effect.

Atmosphere. Dispersion in the atmosphere has been studied extensively and the mathematical techniques for determining the downwind concentration of a pollutant are well developed. Adequate predictions of downwind concentrations can be easily determined providing appropriate data on the source type and nature of the pollution is available.

Ground water. Ground water is meant to imply subsurface water such as the water which is extracted from wells. The entrance of a pollutant into ground water can occur through leaching downward from the surface, from waste burial sites and waste injection wells. Dispersion by ground water has also been extensively studied. The rate of ground water movement depends upon the pressure gradients and the porosity of the media in which it is moving.

Mathematical techniques for determining the downgradient of the concentration of a pollutant are also well developed. However, adequate predictions of the downgradient concentration are possible only if the appropriate geological measurement of pressure gradients and porosity are available. Such measurements require the drilling of numerous test wells and must be performed by experienced technicians. As a consequence, such analyses are usually contracted out to consultants who have the necessary equipment and expertise. Again, environmental groups generally need such analyses only for use in court.

Surface water and ocean. The dispersion of a pollutant in rivers, lakes, bays, seas or the ocean depends upon the depth of the release, the existing currents and the temperature gradients. Techniques for determining the dispersion are available providing the appropriate data has been collected. Again, if the data is not available, most industries and environmental groups contract such analyses out to consultants who have the necessary equipment and expertise.

Distribution. Products are first dispersed by the industry's distribution network. After the product is eventually used, the other forms of dispersion can occur. For example, when a pesticide is sprayed on crops by a farmer, it becomes an air pollutant and it contaminates the ground. The contaminated ground may enter surface waters by erosion or the pesticide may move downward and contaminate the ground water. In addition, pesticide contaminated crops can then become another product (source) as part of the food supply.

In Figure 1, columns 4 & 5 the magnitude of the concern registered against any environmental pollutant is measured in terms of its effects on humans and their environment.

Since the environmental movement began in the 1960s, many industries have, by now, been required to disclose the quantity and nature of their emissions. In addition, an extensive number of studies have been conducted to reveal the environmental effects of these pollutants. As a consequence, there is today a vast amount of data available on the categories listed in columns 4 and 5. Unfortunately, as will be shown subsequently, the data still is not adequate to meet the needs for evaluating the biological effects.

The vast majority of scientists (see Figure 1, column 4) are in agreement concerning the

physical effects of pollution listed in column 4. What controversy exists is related to the time frame that should be applied to reducing the worldwide emission of the gases that produce climate change and acidification. This controversy is fuelled, primarily, by economic factors which will be discussed below in the section on Figure 2.

While Figure 1, column 4 is related to the physical effects of pollution, it is important to note that these effects also lead to biological damage. It has been well reported, even in the mass media, that:

The emission of greenhouse gases is probably causing an increase in the average temperature of the earth's atmosphere. This warming will seriously alter the climate. The climatic change will drastically reduce the crop yields of today's prime agricultural areas and will result in the flooding of coastal areas by the melting of polar ice.

Emission of chloro-fluoro-carbon compounds (CFCs) are depleting the ozone layer of the atmosphere and this can lead to an increase in skin cancer.

Emission of sulphur dioxide and nitrogen oxides are producing acid rain which has already caused serious damage to our forests.

Unfortunately, the scientists in governmental bureaucracies and in industry began to voice concern over these physical effects only after the pollution had produced undeniable damage to the environment. In this respect, it is important to note here that the greenhouse effect of carbon dioxide is not a new scientific discovery. The scientific literature that was published 100 years ago contains articles on the greenhouse effect. Professor Svante Arrhenius wrote a definitive, summary paper on this subject in 1896 (Philosophical Magazine, Vol. 41, Nr. 237, 1896). His estimate of the magnitude of greenhouse warming falls within the range estimated by today's sophisticated computer models.

Data on the uptake of pollutants by plants, animals and humans (see Figure 1, column 5) is essential to tracing the concentration of the pollutants through the food chain in order to determine the ultimate concentration in the diet and tissues of animals and humans. The concentration in tissues is directly related to the potential effect on animals and humans.

Information on the biological effects of pollution comprise the largest assortment of observational and experimental data relative to the problem of environmental pollution. At the same time, the data available fall far short of the information needed. Most of the effects on animals are observed in the field after the pollution has occurred. For example, the brown pelican was almost extinct in California before it was determined that DDT was responsible for making its eggs so fragile that they broke in the nest.

The situation is not much better relative to humans. The effects of pollution on humans range from minor allergic reactions to death from cancer and cardiovascular disease. Pollutants also produce birth defects and cause genetic damage that can affect many future generations. Yet, a 1984 U.S. National Academy of Sciences study indicated that: Sufficient data was available to make a complete health hazard assessment on only ten percent of 3,350 pesticides, only two percent of 3,410 cosmetic ingredients, only five percent of 8,627 food additives and none of 48,523 chemicals in commerce. (U. S. National Academy of Sciences, National Research Council, Toxicity Testing: Strategies to Determine Needs and Priorities, Washington DC, 1984).

These chemicals do not include the unnamed and unknown waste products that are produced during the manufacture of these chemicals. All of these materials, in one way or another and to one extent or another, can be found in the environment and/or in food supplies.

There is actually more data available than the above comments by the Academy would suggest. But, the data are not adequate to assess the health hazards. Dr. Epstein offers one explanation for this inadequacy:

The overwhelming bulk of benefit and risk data, on the basis of which most regulatory decisions are based, comes from the industries being regulated. These data are either generated and interpreted by in-house scientists or by commercial laboratories and universities under contract. In-house scientific staff are not immune from research and development and marketing departments anxious to hurry their product or process into commerce. Industrial contracts with commercial laboratories and universities are usually awarded secretly, without bids having first been solicited on the open market, a practice hardly consistent with the ethos of competitive capitalism. The contractee, anxious about the award of future contracts, is also not immune to unspoken pressures to produce information or interpretations consistent with the perceived interests of the contracting industry. (Sameul S. Epstein, *The politics of cancer,* Anchor Press/Doubleday, Garden City, New York, 1979, p. 299).

Because of this paucity of data, environmentalists must rely on comparative techniques to assess the potential hazard of pollutants. In doing this they compare the chemical composition and structure of a chemical compound, for which there is no data, with another compound or compounds of similar composition and structure, for which toxicity data are available. They then assume that the toxicity of this new chemical has a similar toxicity. This approach is useful but still somewhat tenuous because similar compounds can have large differences in toxicity.

There is no data on the toxicity of the vast majority of chemicals in a group of compounds that are categorized as organochlorine compounds. For those that have been tested, their carcinogenic toxicities range over a factor of one million. This group includes dioxins which are considered to be the most carcinogenic/mutagenic materials known.

In order to properly address the problems associated with the biological effects of pollution, an environmentalist must have training in biology, biochemistry, organic and inorganic chemistry and physiology. The environmentalist must also be familiar with the procedures used in toxicity testing and with the statistical approaches used to analyze the data from such tests. The latter is very important because one of the first things that an environmentalist discovers is: while statistics are not manipulative, manipulators use statistics.

Column 1 of Figure 2, with the exception of TYPE, contains the same information requirements as column 2 of Figure 1. This information is necessary for determining the optimum approach to reducing or eliminating the release of pollutants to the environment.

Depending upon the chemical and physical properties of a pollutant, their emissions can be reduced or eliminated by one or more of the physical or chemical processes listed in Figure 2, columns 2 and 3. Usually, these processes are used in various combinations including combinations of both physical and chemical mechanisms. Except for the modification of the production processes, all of these mechanisms are supplied by companies which produce and install pollution control equipment.

These companies have been quite ready to supply details on the performance and costs of their equipment to environmental organizations. They also supply information on the operating experience obtained from industries that have installed such equipment.

Modification of the production processes is often capable of reducing or eliminating the release of pollutants. A simple example involves the substitution of natural gas for coal in order to reduce sulphur dioxide emissions. A better example is to use methane produced by anaerobic digestion of sewage and agricultural waste as a coal substitute. This eliminates not only the sulphur dioxide, but also the greenhouse effect of carbon dioxide because the waste materials are renewable resources.

Actions such as the substitution of coal by methane produced from waste would not only modify the production process at manufacturing facilities, it would also eliminate or drasti-

cally reduce the size of the coal mining industry. Clearly, in the interest of protecting the environment, the coal industry should, at the very least, be drastically reduced. This will be discussed in more detail in the next section of this report (The first line of defense).

Economic considerations have been the major impediment to the control of environmental pollution (see Figure 2, column 4). Conceptually, the economic questions could be resolved by a risk/cost/benefit analysis. But going from the concept to process is difficult. As we mentioned in the discussion on Swedish law, one difficulty arises because it is often the case that the public takes the risk (health effects) while the company gets the benefit (profits).

Another difficulty involves assigning a monetary value to the risk. What monetary value should be assigned to the development of a fatal cancer in 40 year old man? A value often used in the United States for a cancer death is one million dollars. The only rationale for this value appears to be that it roughly corresponds to an individual's lifetime earnings at the average yearly income.

But more profound questions relate to risks that will adversely affect our children, grandchildren and even several subsequent generations. Among these questions are:

What monetary value should be assigned to the birth of a child with a congenital abnormality?

What is the value to be assigned to an induced genetic mutation that will affect several future generations arising from the individual with the defect?

How do you place a monetary value on the creation of endangered species or on the eventual loss of these species?

How do you assign a value to the production of a climate change that, in fifty years or less, will have devastating effects on a large portion of the world's population?

There is really no education or training that would qualify anyone to assign monetary values to these questions.

It is probably the uncertainties in determining the risks coupled with the inability to assign a monetary value to the effects that served as part of the motivation behind the endorsement, on May 18, 1990, of the precautionary principle by the ministers of the 34 nations at the United Nations Economic Commission for Europe. This principle was part of the Ministerial Declaration on Sustainable Development. It states:

In order to achieve sustainable development, policies must be based on a precautionary principle. Environmental measures must anticipate, prevent and attack the cause of environmental degradation. Where there are threats of serious or irreversible damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation.

This principle is identical to the guiding principle that environmentalists have long accepted as basis for their code of action.

IV. The first line of defense

With respect to the first line of defense, educating the public, Miljöcentrum answers numerous requests for information from individuals and groups. As a response to some of these requests, Miljöcentrum has become a party in Licensing Board hearings and in a court proceedings. In addition, Miljöcentrum originates and/or participates in seminars and presents lectures at public and private meetings, submits articles and press releases to the news media and appears on radio and TV programmes. The Centre has also published numerous topical pamphlets and several books.

To help in educating the public, Miljöcentrum has, beginning in 1972, published a magazine, *Miljö o Framtid* (Environment and the Future). At the present time, eight issues of the magazine are published yearly. Different issues of the magazine have contained articles on essentially all forms of pollution, including:

1. Food additives and contaminants
2. Nitrogen fertilizers, pesticides and herbicides
3. Acid rain, greenhouse gases and ozone depleting chemicals
4. Emission of air and water pollutants by industry
5. Emission of air pollutants by motor vehicles.
6. Nuclear power reactors and radioactive wastes
7. Hazardous chemical wastes

In a positive vein, the magazine contains articles on environmentally friendly technologies such as:

1. Organic farming
2. Energy conservation
3. Solar energy including the use of biomass for energy
4. Methanol made from biomass as a transportation fuel
5. Catalytic convertors for motor vehicle emission control
6. Emission control technology for industry
7. Using wastes for energy after sorting for recycling

The above lists of the subjects that are discussed in the Centre's magazine illustrate the range of scientific and engineering knowledge that is required to fully inform the public relative to environmental hazards and protection. Many of these articles are prepared by the Centre's staff and by other knowledgeable individuals from academia and industries.

A. The nuclear power debate

One of the first major information campaigns originated by Miljöcentrum was initiated in 1972 and it involved the Centre's opposition to the use of nuclear energy for the generation of electricity. As part of this campaign, numerous articles on the hazards associated with nuclear power were published in *Miljö o Framtid.* In addition, Miljöcentrum published several pamphlets on these problems. The articles and pamphlets discussed the following hazards:

The biological effects of radiation,

The chances of major accidents at nuclear power stations,

The catastrophic effects of such accidents,

The inability to safely dispose of the radioactive wastes,

The role of nuclear power in the proliferation of nuclear weapons,

The problem of preventing the acquisition of plutonium by terrorist and irresponsible or maverick nations.

Miljöcentrum also presented this material at public meetings and seminars. This information campaign led to the formation of anti-nuclear groups throughout Sweden.

It is generally conceded that the ensuing nuclear debate was instrumental in the fall of the Social Democrats from power in 1976. They had been in control of the government for the previous 45 years. Only the reactors that were in operation or under construction in 1976 are operating today. The growth of nuclear power was brought to a halt. In 1980 the Swedish voters passed a referendum that requested an early phase out of the existing nuclear power plants in Sweden.

B. Future energy systems

One of the arguments used by proponents of nuclear power is that it was a clean form of energy. In making that claim, the proponents ignored the radioactivity and the other problems associated with nuclear power. A major portion of Miljöcentrum's educational programme has been dedicated to environmentally safe energy sources for the future.

The precautionary principle (discussed in Figure 2, column 4) requires action to anticipate, prevent and attack the causes of environmental degradation. Often this action simply requires the banning of a product such as DDT. In other cases, it will mean eliminating or drastically reducing the size of an entire industry. The need for drastically reducing the coal mining industry was discussed in the section above in Figure 2, columns 2 and 3. This action is needed to reduce the release of carbon dioxide and thereby reduce the possibility of a catastrophic climate change brought about by an increase in the greenhouse gases in the atmosphere.

Moreover, the greenhouse problem is larger than just the coal mining industry. In fact, the greenhouse effect requires not only a drastic reduction in the coal mining industry, but it also requires a drastic reduction in our dependence on other fossil fuels, such as petroleum and natural gas. As a consequence, the greenhouse effect and its amelioration strikes at the heart of our industrialized societies. The vast majority of our manufacturing industries, our electricity generation facilities, our heating systems and our transportation systems are totally dependent on the combustion of fossil fuels.

Clearly, it would be totally unreasonable to simply call for the elimination of fossil fuels. They can only be eliminated if they are replaced by environmentally friendly, alternative forms of fuel and energy. Moreover, since our present societies are almost totally dependent on fossil fuels, it will be necessary to coordinate the change to alternative forms of fuel and energy with every element of our infrastructures. These factors have long been recognized by environmental organizations. The progress toward alternative, environmentally friendly forms of fuel and energy has been a major preoccupation of Miljöcentrum.

1. Alternative to fossil fuels

Ever since its founding, Miljöcentrum has been informing the public concerning the virtues of various approaches to reducing or eliminating our dependence on fossil fuels. These approaches include:

Energy conservation

Direct use of sunlight for space heating

Direct use of sunlight for electricity generation

Windmills for electricity generation

Ocean thermal gradients for electricity generation

Wave action for electricity generation

Biomass as an energy source for heat and electricity generation

Conversion of biomass to gaseous and liquid fuels

Converting waste to energy for heat and electricity generation

Conversion of wastes to gaseous and liquid fuels

After considering all of these possibilities, Miljöcentrum assembled a proposal for eliminating the use of fossil fuels in Sweden. Since Miljöcentrum does not consider nuclear energy to be a viable solution to the replacement of fossil fuels, our proposal also discussed the replacement of nuclear electricity in Sweden.

We shall begin by presenting a viable solution to the replacement of fossil fuels and nuclear electricity that will involve the minimum amount of change in the present energy utilization pattern. This will be followed by a discussion of energy conservation measures that would complement the minimum change proposal.

2. The minimum change solution for fossil fuels

We have called this "the minimum change solution" because it does not involve any alteration in the present energy consumption patterns and permits the continued (and almost exclusive) use of the internal combustion engine in the transportation system.

The solution uses biomass as the total replacement for fossil fuels. The use of biomass will be neutral with respect to the greenhouse effect. The carbon dioxide produced by the combustion of the biomass is equal to the carbon dioxide taken from the atmosphere while the biomass was being produced. The biomass (energy forests) would be produced on 150,000 hectares of marginal or abandoned agricultural land, 850,000 hectares of peatland and 3,000,000 hectares of forest land. The area required for energy forests represents only ten percent of the present Swedish forest area. This represents only 1/3rd of the excess (30 percent) forest land in Sweden.

The technical processes used to convert the biomass to liquid or gaseous fuels are well developed, industrial processes. It is important to note that the technical details for this solution have come primarily from publications by Swedish scientists and technologists. Similar publications can be found in the literature of other industrialized nations.

Transportation. We have chosen methanol as the replacement fuel for transportation. The methanol will be produced from wood that is harvested from energy forests. This production process is fully developed and is similar to the production of methanol from coal or natural gas. Some 3.3 million hectares of energy forest would be required to produce the 86 TWh/yr of methanol needed for transportation. (1 TWh = 1000 million kilowatt hours).

Since methanol is a liquid, the methanol option is almost identical with present use of gasoline and can utilize the present gasoline distribution system with little alterations. During the ten or so years while the size of the industry and its production of methanol are increasing, the methanol can be used as an additive to gasoline. Then, gasoline would be added to methanol and eventually 100 percent methanol would be available.

On a tax-free basis, the price of the 100 percent methanol option is estimated to be more expensive (45 öre/km or seven US cents/km) than gasoline (25 öre/km or four US cents/km). However, as oil becomes scarce around the turn of the century, the price of gasoline may be comparable to that of methanol. At the same time, the imposition of the proposed carbon dioxide tax on gasoline could eliminate this price differential immediately.

Industry. The proposed replacement for fossil fuels in industry is wood from energy forest. Some 700,000 hectares of energy forest would be required to produce the 48 TWh/yr of fuel needed by industry.

Heating. Part of the energy for heating and hot water would be supplied by the unusable portion of sorted municipal, industrial and forests wastes. The remaining part of the energy would be supplied by agricultural wastes and

by lusern that will be grown on 330,000 hectares of excess agricultural land. The lusern and waste would be converted to methane by bacteria. We have included lusern (a legume) because farmers can replenish the nitrogen in their soil by rotating it with other crops.

Using waste and methane as fuels, the total energy needs for heating and hot water can be met by simply changing the existing district heating systems into cogeneration systems. The electricity produced by cogeneration would then be used to drive heat pumps in those houses, apartments and commercial establishments that are not supplied by the district heating systems. The energy use would be 24 TWh/yr of methane, 65 TWh/yr of wastes. The cogeneration will produce 32 TWh/yr of electricity for use in heat pumps.

3. The minimum change solution for nuclear electricity

Nuclear energy can be totally replaced by unused waste and windmills. It is proposed that all of the windmills should be placed in offshore sites. Of course, the electricity could be supplied by a combination of off- and onshore sites. It should be mentioned that the hectares required in this solution represent only a fraction of the area suitable for windmills.

Transportation At the present time only three TWh/yr of electricity is used for transportation. We assumed that one TWh/yr was nuclear electricity. This electricity would be replaced by windmills.

Industry. It is assumed that 1/2 of the electricity used by industry is supplied by nuclear energy. This amounts to 22 TWh/yr and would be replaced by windmills.

Heating. It is assumed here that all of the electricity used for heating and hot water (35 TWh/yr) is supplied by nuclear energy. This is a reasonable assumption since the nuclear power plants are shut down during the summer months for maintenance and refuelling. Similar to the replacement of the heat energy from fossil fuels, unused wastes will supply the energy for cogeneration in existing district heating systems. The electricity would then be used to drive heat pumps in those houses, apartments and commercial establishments that are not supplied by the district heating systems.

Other. This category applies to the use of electricity for such things as lighting, home appliances and office equipment. Of the 46 TWh/yr used for these purposes, only four TWh/yr are assumed to come from nuclear energy. This assumption is compatible with the assumption that all of the electricity used for heating is supplied by nuclear energy. This four TWh/yr will be supplied by windmills.

4. The minimum change and energy conservation

The above proposals did not consider any substitutes for the internal combustion engine. In addition, they did not consider the technologies of solar cells or solar thermal systems for the production of electricity and the technology for solar thermal systems to supply any heating requirements. Although Miljöcentrum strongly endorses these technologies, we shall not discuss them here.

In addition, the proposals above are based upon present day energy consumption patterns. As a consequence, with the exception of heating, the proposals do not consider the potential of energy conservation in any sector. We shall discuss energy conservation measures because energy conservation could reduce the requirements for energy and, thereby, reduce the magnitude of the effort required to implement the minimum change proposals.

Industry, heating and other sectors. The minimum change proposal for heating actually includes two conservation measures (cogeneration and heat pumps). Some additional energy saving could be achieved by improving insulation in what are termed sick buildings, but we have seen no estimates of the amount that could be saved. Nor have we found an adequate data base upon which we could make our own estimates. Our impression is that, through the improvement of sick buildings, the total energy

consumption for heating could be reduced by some ten percent, but, not much more.

Similarly, we have not found any estimates of the possible reduction in energy use that could be achieved by conservation in industry and we have not found an adequate data base upon which we could make our own estimates. Again, our impression is that the energy consumption by industry could be reduced by some ten percent, but, not much more.

About 1/3 of the electricity used in the other sector is used for lighting and 2/3 for the operation of home appliances and office equipment. The total use of electricity in this category is 46 TWh/yr. Modern appliances (refrigerators, etc.) use less than 1/2 the energy used by older appliances. New florescent light uses about 1/4th the energy used by incandescent light. When the older appliances are replaced by newer, energy efficient ones and as the new florescent lights replace the incandescent lights, the electricity used in the other sector could be reduced by at least 50 percent (23 TWh/yr).

In summary, we estimate that, over the next few years, 32 TWh/yr of energy forest and windmill electricity could be saved by energy conservation in industry and other sectors. The 32 TWh would be composed of five TWh of energy forest in industry and 27 TWh of windmill electricity (four TWh in the industry sector and 23 TWh in the other sector).

It is interesting to note that the reduction of 27 TWh/yr in electricity use represents 43 percent of present day nuclear electricity production. The 27 TWh/yr is the same as the windmill generated electricity proposed above. In other words, energy conservation can be as important as alternative energy sources.

Transportation. Among the minimum change solutions, transportation requires the greatest quantity of energy forest (70 to 80 percent). It should be noted here that the energy requirement is based upon the use of methanol in engines that were designed specifically for gasoline. From an energy conservation point of view, if the engines were designed for methanol, they would require less energy forest.

Apart from engine design, the major opportunity for energy conservation in the transportation sector is to be found in collective travel -- the use of car pools, buses and trains. By increasing the average occupancy of automobiles to two per automobile through the increased use of car pools and by switching the long distance transport of goods to railroads, the energy forest requirement for transportation could be reduced by 16 percent.

If, in addition to the above changes, the automobile passenger km were reduced from 80 to 60 billion passenger km through greater use of buses and trains, the energy forest requirement for transportation could be reduced by 24 percent.

Thus, fairly simple and reasonably achievable conservation strategies could reduce the requirement for methanol production by 16 to 24 percent. The magnitude and the cost of the effort to replace the oil used for transportation would be reduced by the same amount. These conservation strategies do not involve technology -- they only require the willingness of the public to alter their mode of transportation. Moreover, it is important to note that these alterations primarily involve an increase in the use of car pools, buses and trains in travelling to and from work.

The details of the minimum change solution are summarized in Figure 3 on page 24. Figure 3 also summarizes the savings achievable through energy conservation.

5. A Miljöcentrum campaign for a future system

The discussion above demonstrates that it is entirely possible to replace all fossil fuels and nuclear electricity used in Sweden by biomass and windmills. The major source of biomass would be energy forests. However, included in the biomass are lusern and unused municipal, industrial, agricultural and forest wastes. The technology necessary is readily available. In

fact, the technology has been available for decades. All that is needed is the desire on the part of government and industry to implement a process that will bring this technology into use. Thus the difficulty lies in the non-technological, educational aspects of the solution to these problems.

While Miljöcentrum is dedicated to promoting each of these solutions including energy conservation and the direct use of solar energy, the Centre has begun a concerted campaign to overcome the inertia associated with the creation of a biomass to methanol industry. The Centre has discussed the virtues of such an industry with officials of local governments and businessmen in local communities. Discussions have also been held with executives in the oil and automobile industry and with agricultural and forestry personnel. These discussions have been successful in creating enthusiasm for initiating the planting of energy forest and the construction of facilities to convert biomass to methanol. In fact, Miljöcentrum's proposal for the construction of a facility to convert biomass to methanol is now under consideration by the officials and businessmen of one community.

V. The last line of defense

Environmental organisations need the knowledge necessary to confront different industries that have different forms and mechanisms of pollution. A polluting industry, on the other hand, needs only to develop the expertise relevant to their own form and mechanism of pollution. This will be illustrated in subsequent sections where the technical contents of a Licensing Board hearing and of a court action. Miljöcentrum was a participant in both proceedings.

A. Licensing board hearing

The Licensing Board hearing chosen as the example of a hearing, in which Miljöcentrum participated, is associated with the request of Billerud AB for their plant Gruvöns Bruk in the county of Grums, Sweden. Gruvöns Bruk is a paper and pulp mill. Billerud AB is a daughter company of Stora AB which is the largest pulp and paper company in Sweden and in Europe. When Stora's plants in Canada and the USA are included, it is one of the largest pulp and paper companies in the world.

Gruvöns Bruk had initially been issued a licence in 1982. The licence contained limits for the release of specific pollutants to water. These were provisional or temporary limits that would be reviewed at a later date. Although it was well recognized at that time that chlorinated organic compounds (TOCL) were hazardous, the 1982 licence did not limit the release of this material. These compounds are formed during the process of bleaching sulphate pulp with chlorine.

It was well known that diseased and malformed fish could be found in the vicinity of paper mills. Clearly, this indicated that the releases from the mills were toxic. Subsequent to 1982, high levels of TOCL were, predictably, being measured in fish. Finally in 1987, encouraged by the Environmental Protection Board, the Licensing Board began to include a permitted level for the release of TOCL to water in the licences. Nevertheless, in 1988, when the Licensing Board amended the Gruvöns Bruk licence, it still did not contain a limit for TOCL releases to water.

In 1988, Gruvöns Bruk asked the Licensing Board for permission to increase its production of bleached sulphate pulp from 280,000 tons/year to 310,000 tons/year. At the same time, because of the new TOCL requirement imposed by the Licensing Board, Gruvöns Bruk also requested a TOCL release limit at two kg per ton of bleached sulphate pulp. Their justification for this release limit appears to be that this was the amount that they were currently releasing.The Licensing Board was required to conduct a hearing on this request. Miljöcentrum and the Environmental Protection Board became participants in this hearing.

Miljöcentrum proposed that the Licensing Board set a limit for TOCL releases that was ten times smaller than the request of Gruvöns Bruk; i.e., 0.2 kg/ton of bleached sulphate pulp. This request was supported by presenting evidence which demonstrated the existence of a new process that could substantially reduce the amount of chlorine required for bleaching. This new process is called the Prenox process. It is important to note that most of the development work on this process was conducted at Chalmers University of Technology in Göteborg, Sweden.

The Environmental Protection Board also participated in the hearing. They argued that Gruvöns Bruk should keep their total yearly TOCL releases at the level of 390 ton/year. Thus, the Environmental Protection Board proposed a release rate that was also lower

than the request made by Gruvöns Bruk; i.e., 1.26 kg TOCL per ton of bleached sulphate pulp when the pulp production reached 310,000 ton/year. This recommendation only required the optimization of the control over the plant's existing bleaching process.

The Licensing Board issued its decision in August 1989. The board, while recognizing the existence of the Prenox process, ruled that Gruvöns Bruk should keep their TOCL releases to water at or below 1.3 kg/ton of bleached sulphate pulp.

1. Economic considerations

Unfortunately, although the law suggests that risk/cost/benefit analysis should be included in the Licensing Board's decision making process, the Board has only required an analysis of the costs. It appears that their philosophy is that emissions should be reduced if the costs are not too high.

Miljöcentrum presented evidence that the cost of installing the Prenox process would be 100 million Swedish kronor (SKr). Gruvöns Bruk estimated the cost would be 175 million SKr. Using the company's installation estimate, Miljöcentrum calculated that the cost over a ten year period (over which the equipment cost could be written off) would be 16.5 million SKr per year. This estimate represents only seven percent of the 250 million SKr per year profit recorded by Gruvöns Bruk. Either this economic argument did not appear to represent a major factor in the Licensing Board's decision or they determined that the cost (although only a small fraction of the yearly profits) was too high.

As we mentioned in the discussion of Figure 1, column 5, the precise toxicity of this mixture of organochlorine compounds is unknown. There is, however, no doubt that they are carcinogenic, mutagenic and capable of producing birth defects. Moreover, they are persistent and, therefore, they will accumulate in the environment. It would not be unreasonable to propose that the release of these materials from Gruvöns Bruk could, each year, produce one premature cancer death, one genetic mutation and one birth defect. While this proposal cannot be proven, it, also, cannot be dismissed as unreasonable. Based on the above cost estimate, the cost of reducing these three effects would be 5.5 million SKr (16.5/3) per effect. Since, the genetic mutation could affect children born in several future generations, the cost per effect would be more like 2.7 million SKr (450,000 US$).

These costs are rather small amounts to put on the value of human life. Moreover, they do not include any allowance for the damage to other life forms in the environment. Clearly, this is a situation where the precautionary principle that was discussed relative Figure 2, column 4 should be applied.

2. Miljöcentrum's appeal

Miljöcentrum's only recourse to the decision of the Licensing Board was to appeal to the Ministry of the Environment. In this appeal, Miljöcentrum repeated its arguments before the Licensing Board and, in addition, pointed out that two recent licensing decisions related to paper and pulp companies had included a condition that the companies investigate the possibility of reducing their TOCL releases to a level of 0.5 kg/ton of bleached sulphate pulp. These companies were directed to respond by the end of 1991.

The Ministry of the Environment determined that the TOCL releases to water should be kept at or below 1.2 kg/ton of bleached sulphate pulp when the production reached 310,000 tons. This was slightly lower than the value of 1.3 kg proposed by the Licensing Board. But more importantly, the Ministry supported Miljöcentrum's appeal by ruling that Gruvöns Bruk had to investigate the possibility of reducing the releases to less than 0.5 kg/ton of bleached sulphate pulp. Gruvöns Bruk was directed to complete this study and report back to the Licensing Board no later than the end of 1992.

Since Miljöcentrum included the cost analysis in its appeal, it is reasonable to assume

that the Ministry did not necessarily consider that the costs were excessive. Perhaps, they were applying the precautionary principle.

3. Results

Since Stora is one of the world's largest producers of pulp and paper, it is impossible to imagine that its technical experts were unaware of the possibilities for reducing TOCL releases. Thus, it was totally irresponsible for these specialists to suggest to the Licensing Board that they could not reduce their TOCL releases below two kg/ton of bleached sulphate pulp by optimizing their existing processes. Moreover, this irresponsibility was augmented by their failure to propose the larger reductions in TOCL releases that were possible through application of the Prenox process. This is particularly true in this case, since the process was developed in Sweden.

The absence of limits for the release of TOCL to water before 1988 is an example of the failure of the civil servants in the Environmental Protection Board to perform their jobs correctly. These civil servants shouid have petitioned the Licensing Board to place TOCL release limits in the licences much earlier. However, they must be given some credit for suggesting that Gruvöns Bruk could reduce its TOCL releases by optimizing their existing processes. But then, they again demonstrated a lack of integrity by not proposing that the Prenox process could lead to much more substantial reductions in the TOCL releases to water.

Finally, it is difficult to understand why two Licensing Boards should recognize the potential for reducing the TOCL emissions to less than 0.5 kg/ton of bleached sulphate pulp while a third would later choose to ignore this possibility. Was this simply a failure to review previous decisions and the basis for those decisions? Most systems of law take notice of precedent.

It is clear that, without the intervention of Miljöcentrum, Gruvöns Bruk would have been given permanent permission to release an excessive amount of TOCL to water. Now, at least, Gruvöns Bruk will have to prove, in a future hearing, that it is not possible to reduce their TOCL releases below 0.5 kg/ton of bleached sulphate pulp. Miljöcentrum will have to participate in this future hearing in order to ensure that the facts are properly disclosed and analyzed.

B. Lawsuit

In 1988, Miljöcentrum initiated a lawsuit against Höganäs Kantal on behalf of 91 residents who were living in the vicinity of the Höganäs Kantal facility. The plant produces a variety of metal alloys and it was releasing a mixture of metallic powders to the atmosphere. The primary component of the powders was iron. The powders also contained copper, nickel, chromium, cobalt, molybdenum, manganese, zinc, lead, tungsten and cadmium. Some of these metals are known to be toxic. In addition to polluting the air the residents were breathing, these powders were contaminating their vegetable gardens and were being deposited on and in their houses.

The lawsuit involved a claim for damages in the amount of 14.5 million kronor (MSKr). The damages were for the loss of property values caused by the deposit of the metal powders on the houses of the plaintiffs. This amount was based upon an analysis performed by a real estate consultant hired by Miljöcentrum. The claim was based upon the difference in the actual sale price of the homes in the plaintiffs neighbourhood compared with homes more distant from the plant.

Prior to filing the lawsuit, in 1987, Miljöcentrum had collected grass, fruit and vegetable samples from the lawns and gardens of the plaintiffs.

They also placed grass plots in the plaintiffs neighbourhood and at distant location, some in neighbouring towns. Samples of the grass in these plots were also collected. All of these samples were analyzed by a consulting

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analysis firm. The samples from the plaintiffs neighbourhood, compared to more distant samples, contained much higher levels of the metals that were emitted by the Höganäs Kantal facility.

After filing the lawsuit, Miljöcentrum was granted access to the Environmental Protection Board's files on the Höganäs Kantal facility. As it developed, however, the Board had a separate file that they kept hidden. They were ordered to release this file. The file indicated that, between 1982 and 1985, the company had been releasing lead from the chimney of its smelter. This was illegal because their licence had no provision for such a release. The lead was a contaminant in the fuel oil that was being used as a heat source in the smelter. Obviously, the company preferred the contaminated oil because it was cheaper than uncontaminated oil.

The Environmental Protection Board should have stopped these emissions in 1982 when they first learned about them; but instead, the Board let them continue for three years. This is a classic example of a bureaucracy (that is supposed to protect the environment) protecting an industry rather than the environment.

The company also hired a real estate consultant who concluded that the damage resulting from the lower selling prices of the houses was much less than the plaintiffs claimed. His estimate was about one MSKr. The discrepancy between the estimates occurs because five houses were sold, after the lawsuit was filed, in 1988. The selling price for one of them was 75 percent of the tax value. This price was equivalent to the selling price recorded for the previous few years. However, the other four houses sold for 175 percent to 220 percent of the tax value. The company's consultant relied heavily on these 1988 sales in making his estimate. The plaintiffs consultant rejected the 1988 sales in making his estimate.

The company presented measurements, made by a consulting firm, of powder samples collected in the vicinity of the plant and from remote locations. The company also presented data that were to represent the direction of the wind that brought the powder to the collectors. The samples from both types of collectors were analyzed for their content of different metals. This was not much of a defense however, because when properly presented, they indicated a higher concentration in the vicinity of the plant.

There was a major flaw in the data from these collectors. Actually, the collectors were more appropriate for collecting rain than for measuring the material released by the factory. These collectors were efficient in collecting particles larger than ten microns in diameter. These larger particles literally fall out of the atmosphere. As the particle diameter falls below ten microns, the particles behave like aerosols and remain suspended in the air and subject to turbulent diffusion. They are removed from the air by turbulent impaction.

As a consequence of this difference in the process of removal from the atmosphere, as the particles move downwind from the source, the larger particles fall to the ground. At a certain distance downwind, depending upon the height of the release, only the small particles remain. Thus, the measurement of the particle that literally fall out of the sky has little to do with the particle that remain suspended and are removed by turbulent impaction. Under cross-examination, this flaw was admitted by the company's consultant. This was a major flaw because 90 percent of the material emitted by the factory was in particle sizes below ten microns. Hence, the company's data was next to meaningless.

On the other hand the smaller particles are deposited by turbulent impaction on grass and on the sides of houses. Thus, the grass samples analyzed by Miljöcentrum were measurements of the deposit of these smaller particles.

Before adjourning to consider their decision, the members of the court made a personal inspection of each of the 91 residences that were part of the complaint. During this walk-around inspection, Gillberg, the Director of Miljöcentrum, demonstrated four tests to the court:

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1) The drain pipe test wherein the side of the drainpipe facing the factory was dirty and rough to the touch. The other side was clean and smooth.

2) The outdoor thermometer test which was identical to the drain pipe test.

3) The eaves test wherein the portion of the exposed side of a house, which was protected from rain by the eaves, was dirtier than the rain washed portion.

4) The magnet test was undoubtedly the most convincing since iron was the major constituent of the released powder. The magnet was dragged through the grass or over a dirty portion of a house and it became covered with iron powder.

This walk-around inspection was undoubtedly the major, if not the sole, evidence that caused the court to decide that the company was responsible for damage to the property of the residents. However, in awarding the damages, it accepted the company's estimate and awarded a total of only 848,000 SKr.

The plaintiffs filed an appeal with a higher court. However this appeal was never heard because the residents and company agreed on an out-of-court settlement of 2.2 MSKr for the damages.

The primary purpose of the lawsuit was not to recover damages but to pressure the company into significant reductions in its emissions. The lawsuit was the only approach that the citizens had. The Environmental Protection Board refused to recommend that the licensing hearings should be reopened. These bureaucrats were again protecting the industry rather than protecting the environment.

The lawsuit served its primary purpose. Höganäs Kantal invested some 50 MSKr in additional pollution control equipment. It was this investment, made by the company while the case was in appeal, that prompted Miljöcentrum to agree to the out-of court settlement. This equipment has reduced their emissions from 500 tons per year to only 20 tons. The property values of the residents have now returned to normal and so has the air that they breathe.

Figures

FIGURE 1: INDUSTRIAL POLLUTION

INDUSTRIES	SOURCE DISCRIPTION	DISPERSION	EFFECTS	
*Manufacturers	TYPE	ATMOSPHERE	PHYSICAL	BIOLOGICAL
*Electricity generation	Point	GROUND WATER	GLOBAL	UPTAKE by
*Refineries	Volume	SURFACE WATER	Climate change	Plants
Petrochemical	Line	OCEAN	Ozone depletion	Animals
*Chemical	Product	DISTRIBUTION	Acidification	Humans
*Pharmacuetical	EMISSIONS to		LOCAL	EFFECTS on
Mining	Air		Smog reactions	Plants
*Smelters	Water		Property damage	Animals
*Agriculture	Ground		Soil erosion	Humans
Food processing	NATURE of the POLLUTION			
Forestry	Chemical composition			
*Pulp and paper	Physical properties			
*Waste disposal	Radioactivity			
*Transportation	Particle size			

* Industries that Miljocentrum has chalenged in Licensing Board hearings or in court proceedings.

FIGURE 2: POLLUTION CONTROL

POLLUTANT	PHYSICAL MECHANISMS	CHEMICAL MECHANISMS	ECONOMICS
EMISSIONS to	MODIFICATION of the	MODIFICATION of the	RISK
Air	PRODUCTION PROCESSES	PRODUCTION PROCESSES	COST
Water	ELECTROSTATIC PRECIPITATION	PRECIPITATION	BENEFIT
Ground	ION EXCHANGE	SOLUBILIZATION	
CHEMICAL COMPOSITION	ADSORBTION	DISTRUCTION	
PHYSICAL PROPERTIES	SOLUTION	Chemical	
Radioactivity	FILTRATION	Catalytic	
PARTICLE SIZE	CHANGE OF STATE	Bacterial	
	SEDIMENTATION		
	Centrifugation		

FIGURE 3: SUMMARY OF OUR PROPOSED SOLUTION FOR THE REPLACEMERNT OF OIL, OTHER FOSSIL FUELS AND NUCLEAR ELECTRICITY WITH SOLAR ENERGY AND BIOMASS

REPLACEMENT WITHOUT CONSERVATION	
Energy forests	
	Grown on 150 000 hectares of abandoned/marginal agricultural land,
	850 000 hectares of peatland and 3 000 000 hectares of forest land
use	as172 PJ (48 TWh) of fuel for industry and
	to produce 310 PJ (86 TWh) of methanol as a fuel for transportation
Municipal, industrial and forest wastes	
use	as 234 PJ (65 TWh) of fuel for cogeneration in district heating systems
Agricultural wastes and lusern	
	Lusern grown on 330 000 hectares of surplus agricultural land
use	to produce 86 PJ (24 TWh) of methane as a fuel for
	cogeneration in district heating systems
Cogeneration in district heating systems	
	Produces 114 PJ (32 TWh) electricity
use	to operate heat pumps in buildings not supplied by district heating systems
Windmills	
	Placed at offshore locations
use	to generate 97 PJ (27 TWh) of electricity
REPLACEMENT WITH CONSERVATION	
Energy forests	
	Grown on 150 000 hectares of abandoned/marginal agricultural land,
	850 000 hectares of peatland and 2 100 000 hectares of forest land
use	as 155 PJ (43 TWh) of fuel for industry and
	to produce 234 PJ (65 TWh) of methanol as a fuel for transportation
Municipal, industrial and forest wastes	
use	as 202 PJ (56 TWh) of fuel for cogeneration in district heating systems
Agricultural wastes and lusern	
	Lusern grown on 330 000 hectares of surplus agricultural land
use	to produce 86 PJ (24 TWh) of methane as a fuel for
	cogeneration in district heating systems
Cogeneration in district heating systems	
	Produces 103 PJ (29 TWh) electricity
use	to operate heat pumps in buildings not supplied by district heating systems
ENERGY SAVINGS = (without conservation) MINUS (with conservation)	
Energy forests	
	224 PJ (62 TWh) grown on 900 000 hectares of forest land
Municipal, industrial and forest wastes	
	32 PJ (9 TWh)
Windmills	
	97 PJ (27 TWh) of electricity

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